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Using Hydrogeomorphic Surfaces for Delineating Floodplains: Black Water Creek Test Reach Within the Upper Puerco Watershed, Navajo Nation

The Navajo Nation in Arizona, New Mexico, and Utah has an immediate need for a floodplain management plan and relevant floodplain information to promote the prudent use and management of the Navajo Nation's floodplains, protect existing property and lives, and serve as a basis for future development. Although the Navajo Nation is sparsely populated, the area has great potential for economic growth. The Navajo Nation's Department of Water Resources, Water Management Branch, has identified seven primary and twelve secondary growth and development centers, and it is anticipated that six additional development centers will emerge.

As part of a long-term effort to establish flood hazard information for the Navajo Nation, a planning-level hydrogeomorphic floodplain delineation was performed in September 2004 to approximate the 100-year floodplain for a test reach of Black Water Creek within the Upper Puerco watershed. This hydrogeomorphic analysis was performed to provide the approximate location of the bankfull channel, active floodplain and less frequently flooded terrace floodplains. These features are interpreted to represent the 2-, 10-, and 100-year inundation levels, respectively. The hydrogeomorphic approximation relies on physical and biological indicators recognized in the field and on aerial photography to delineate hydrogeomorphic floodplain locations. In most cases the hydrogeomorphic floodplain position is interpreted using both physical and biological indicators at each site, reducing the reliance on any one indicator. This method provides insights into the temporal and spatial variability of hydrogeomorphic positions in the landscape, leading to a better understanding of flood potential. This method has been used in numerous watersheds in southern California and Nevada for wetland-based watershed evaluations (Lichvar et al. 2003, Lichvar and Ericsson 2004). Overall, the hydrogeomorphic floodplain delineation will be useful for identifying allowable elevations for new construction within the Navajo Nation. In addition it will assist in satisfying FEMA zone A (base 100-year flood) regulatory requirements (FEMA 1995) and validating preliminary HEC-RAS hydrologic models.

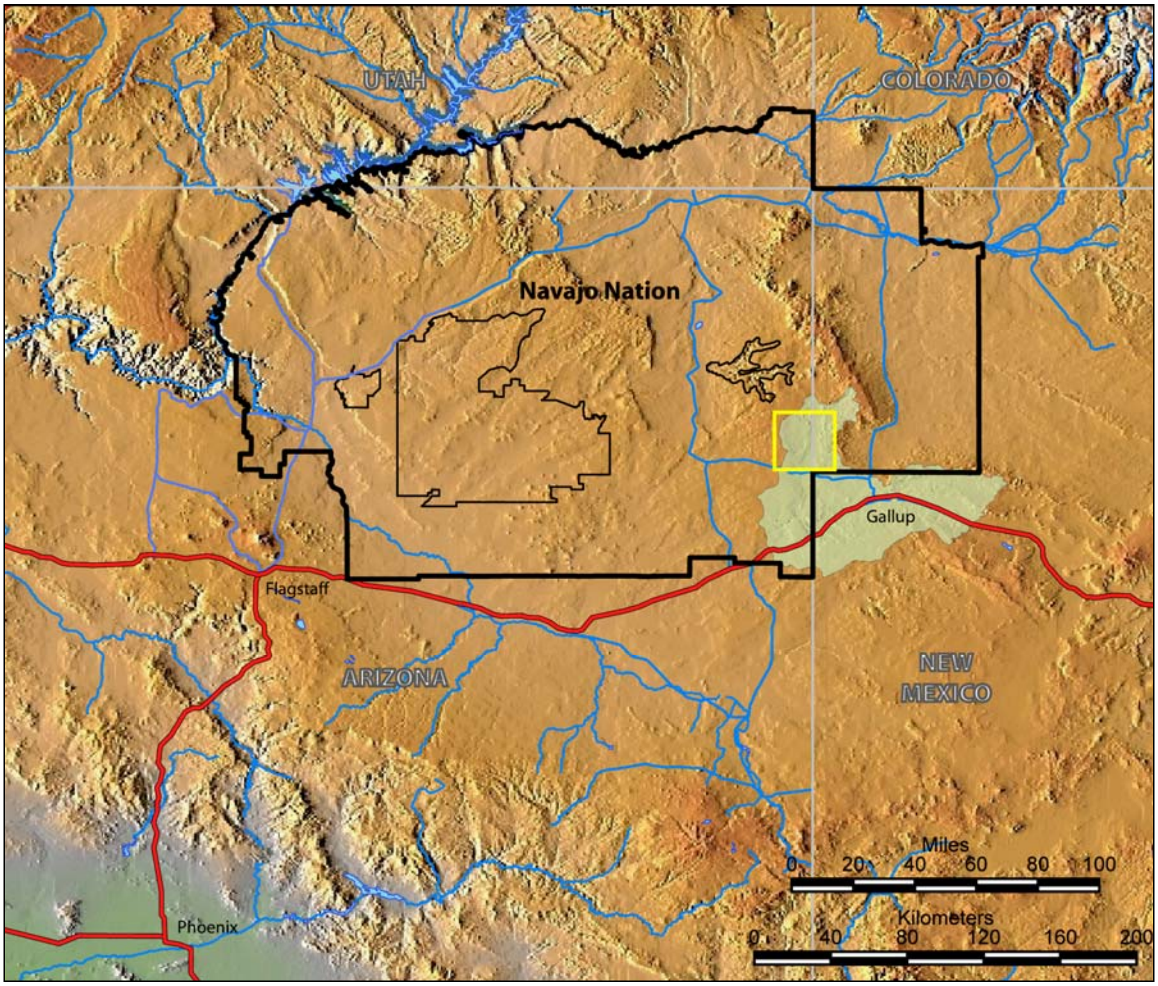

Figure 1. Location map showing the Navajo Nation boundary (Black), the Upper Puerco watershed (green) and the Black Water Creek test reach (yellow).

Study Area

The Navajo Nation encompasses approximately 27,000 square miles in the Four Corners region of the southwestern United States (Fig. 1). This study focused upon a ten-mile reach of Black Water Creek and the tributaries feeding it within the Upper Puerco watershed between the towns of Fort Defiance and Window Rock. State Highway 264 and Indian Route 7 bound the southern and northern boundaries of the study area, respectively. The eastern and western lateral boundaries are bound by the extents of the Upper Puerco Watershed (Fig. 2).

Methods

Mapping Protocols

Potential hydrogeomorphic floodplains were initially identified by interpretation of digital orthoquads (DOQ) imagery obtained from the Arizona Regional Image Archive and New Mexico Resource Geographic Information System Program (via the Internet). Hydrogeomorphic floodplains were delineated in the field using the DOQs within a customized geographic information system (GIS) develop by CRREL on a Fujitsu 3500 Stylistic pen tablet computer. All mapping was at a scale of 1:4800, with a minimum mapping unit size of approximately 405 m^2 (0.1 acres). Using GIS in the field allowed us to view supporting spatial databases (i.e. roads, contours, topographic maps, etc) to aid in locating, identifying, and interpreting hydrogeomorphic floodplains.

Tributary ephemeral and intermittent streams relevant to the test reach were also identified and mapped in the field. The vast majority of these tributary streams were mapped as single-line features because of their narrow width, resulting from their position in the landscape, anthropogenic alteration, or other natural influences resulting in channel incision. In some instances, major tributary streams exceeding 10 ft wide were mapped as hydrogeomorphic floodplain units.

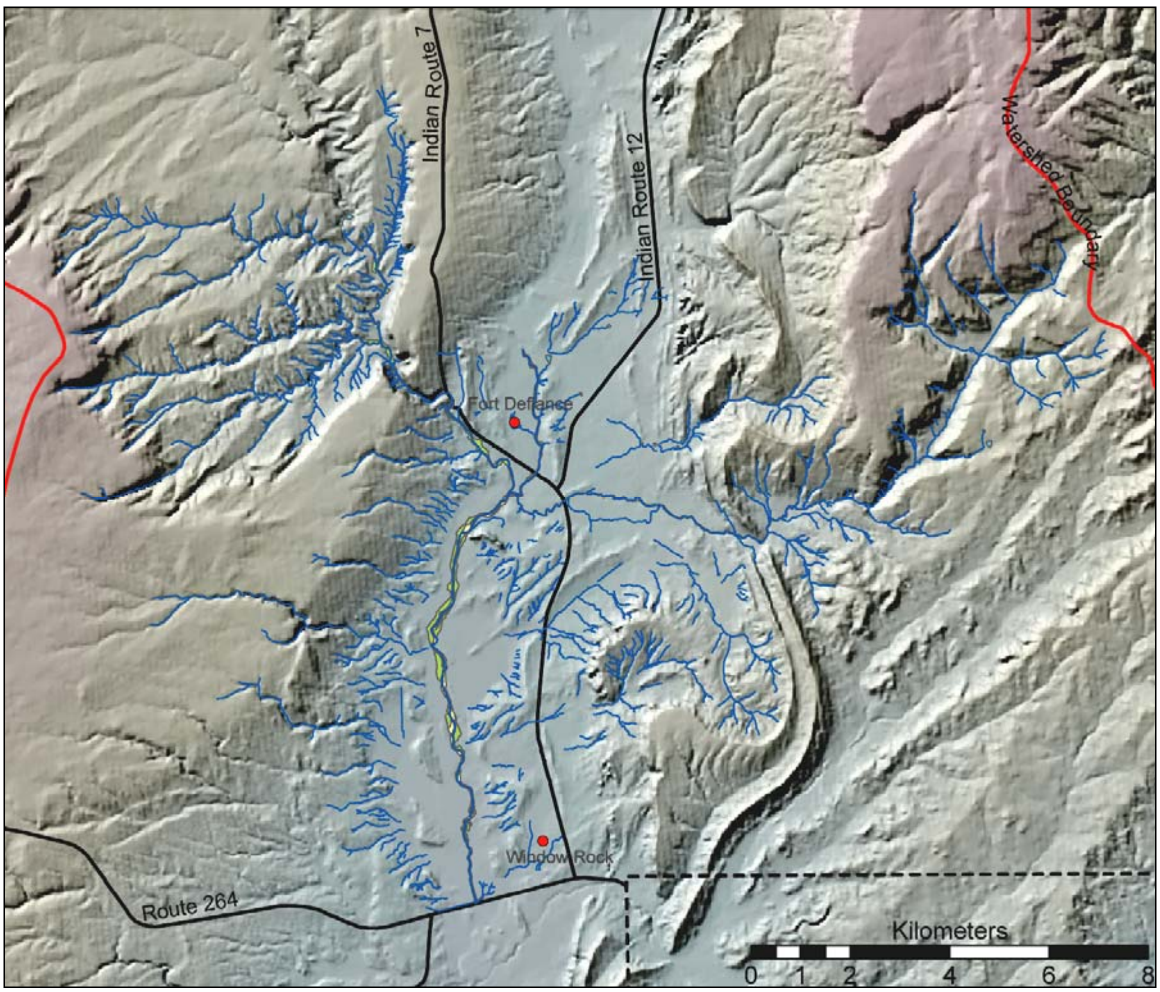

Figure 2. Detailed location map of the Black Water Creek test reach showing the overall extent of the CRREL hydrogeomorphic field mapping (blue lines) within the Upper Puerco watershed boundary (red) in September 2004.

Hydrogeomorphic Floodplain Classification

For this study, hydrogeomorphic floodplain units were mapped for the purpose of indicating flood frequency for use in delineation. Typically, floodplain terraces develop on Strahler stream types that are second order, third order, and greater (Strahler 1952). First-order streams typically lacked floodplain terraces because they are located on steeper slopes, have smaller drainage areas, and are confined to bedrock channels that limit their ability to create floodplain terraces.

The floodplain can be divided into bankfull, active floodplain, and terrace hydrogeomorphic surfaces using surface geomorphic features that represent different flood return intervals (Fig. 3). The bankfull surface can be identified in the field by bed and bank features resulting from frequent discharges (Riggs 1985) that correlate to specific recurrence intervals (Leopold et al. 1964, Rosgren 1996). These bed and bank features develop from frequent discharges corresponding to return flood intervals of 1.4–1.6 years. In addition to bed and bank features, other field features associated with the bankfull channel are sparse vegetation cover and recently deposited fluvial materials.

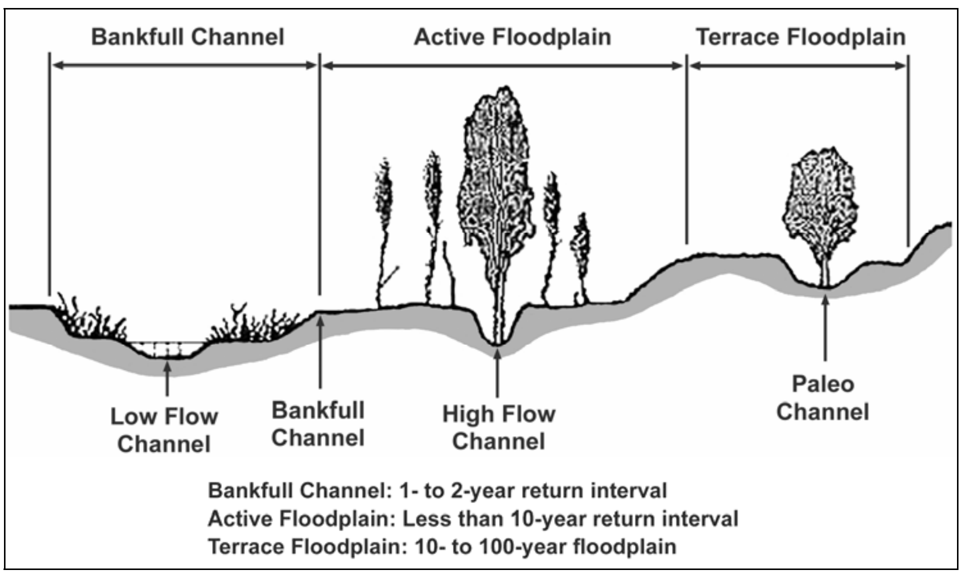

Figure 3. Typical arid southwestern stream cross section and its associated hydrogeomorphic floodplain units. (From Lichvar et al. 2003.)

The active floodplain is typically a flat to gently sloped surface adjacent to the bankfull channel that receives frequent overbank flow (Williams 1978, Province of British Columbia 1995, Rosgren 1996). The active floodplain is less well defined than the bankfull surface. It is flooded every few years and is less extensive than the terrace floodplain. The active floodplain surface can be connected to high flow channels that traverse parts of older fluvial terraces. Active floodplain surfaces generally represent a 2- to 10-year recurrence event (Riggs 1985).

Terrace floodplains are located above bankfull and active surfaces. These alluvial terraces were formed when the river flowed at higher water and deposition levels than present (Graf 1988). These terraces occasionally flood in western riparian systems as a result of short-term heavy and long-term moderate rain patterns (Graf 1988, Osterkamp and Friedman 2000). Such infrequent flood events inundate most or all of the bottomland features, including dry alluvial terraces. Most parts of the terrace floodplain are considered to be within the 100-year floodplain recognized by the Federal Emergency Management Agency (FEMA 1995).

Results

Three hydrogeomorphic floodplain units were identified in the Black Water Creek test site: bankfull channel, active floodplain, and terrace floodplain (Fig. 3 and 4). The bankfull channel, in this study, represents the most recent and frequently flooded area. The active floodplain is the low floodplain adjacent to the bankfull channel; it contains

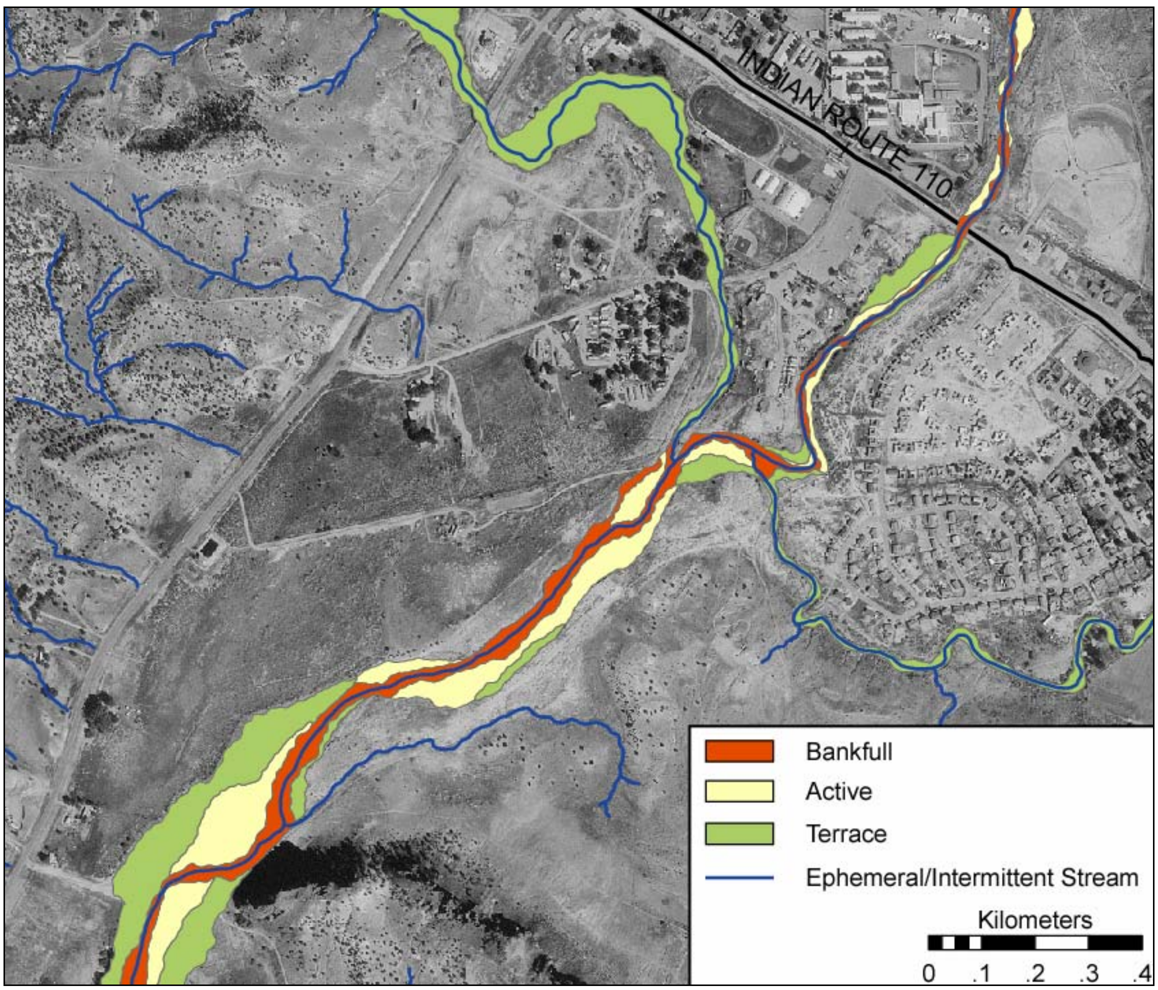

Figure 4. Detailed hydrogeomorphic floodplain units, superimposed on USGS DOQ imagery, that were delineated for a small area of the Black Water Creek test reach. The confluence of two tributaries with the main channel in this developed area illustrates the need for accurate floodplain maps to predict potential flood hazards.

indicators associated with frequent overbank flooding. These indicators include high flow channels, unvegetated surfaces, bed and bank, and a break in slope. The terrace floodplain is topographically above the active floodplain and contains features associated with infrequent flooding and seasonally wet areas. Indicators in this terrace are driven by larger and less frequent overbank flooding, local precipitation, and occasional groundwater discharge within paleo channels and other depressional features. Often there is a distinct change in vegetation community from the active floodplain to the terrace floodplain. The cross section illustrated in Figure 3 represents the idealized floodplain development, but in some instances one or more positions may be lacking because of anthropogenic influences, local soil conditions and morphology, or local climatic influences.

Within the 8.5-mile Black Water Creek study reach, we delineated 184.56 ha (456.05 acres) of hydrogeomorphic floodplains and 386.83 km (240.36 miles) of ephemeral and intermittent streams. Table 1 presents the area for each hydrogeomorphic map unit delineated in the main stem channel, not including the tributaries, for the test reach.

Table 1. Summary of area identified for each hydrogeomorphic position.

	Hectares	Acres
Bankfull Channel	26	65
Active Floodplain	36	89
Terrace Floodplain	53	131

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Acknowledgments

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